Spin Structure Functions of the Deuteron

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Overview

Introduction

- Asymmetries and spin structure functions
- "Neutron" targets?

Example: The EG1 Experiment in CLAS

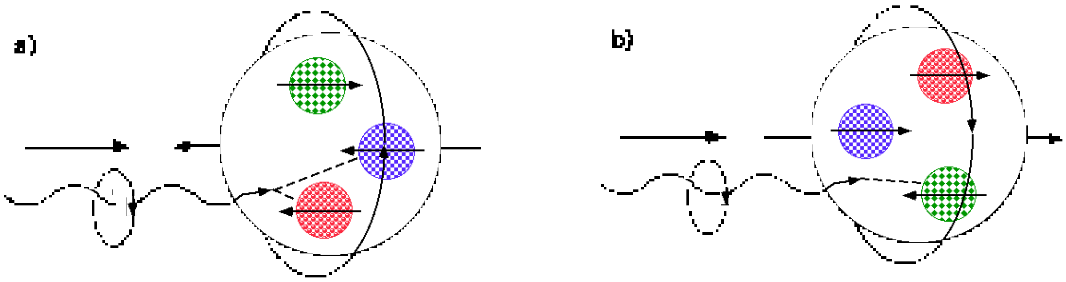
- Experimental setup
- First results on ND_3
- Outlook

From Nuclei to Nucleons

- Nuclear effects on spin structure functions
- Example: g_1 for the deuterium
- World data for ^3He vs. D

Conclusions

Longitudinal SpinAsymmetry:



(**ν,q**)

$\sigma_T^{1/2}(\nu)$ $\sigma_T^{3/2}(\nu)$

$$\text{Photon Asymm.:}\ A_1\left(\nu,Q^2\right)=\frac{\sigma_T{}^{1/2}\left(\nu,Q^2\right)-\sigma_T{}^{3/2}\left(\nu,Q^2\right)}{\sigma_T{}^{1/2}\left(\nu,Q^2\right)+\sigma_T{}^{3/2}\left(\nu,Q^2\right)}$$

$$\text{Electron Asymm.:}\ A_{\parallel}\left(\nu,Q^2\right)=\frac{\sigma^{\uparrow\downarrow}-\sigma^{\uparrow\uparrow}}{\sigma^{\uparrow\downarrow}+\sigma^{\uparrow\uparrow}}=D(A_1+\eta A_2)$$

Momentum transfer $Q^2 = \mathbf{q}^2 - \nu^2$

Final state invariant mass $W^2 = (M+\nu)^2 - \mathbf{q}^2$

Spin Structure Functions:

$$g_1(x,Q^2)=\frac{\nu^2}{q^2}F_1\left(x,Q^2\right)\left[A_1(x,Q^2)+\frac{Q}{\nu}A_2(x,Q^2)\right]$$

Momentum fraction of struck quark in Breit frame $x=\dfrac{Q^2}{2M\nu}$

Light cone fraction of struck quark $\xi=\dfrac{p_q^0+p_q^3}{P_N^0+P_N^3}=\dfrac{Q^2}{M(q+\nu)}$

Why Neutrons?

Bjorken Sum Rule (for Q$^2 \to \infty$)**:**

$$\int_0^1 \left[g_1^{\,p}(x) - g_1^{\,n}(x)\right]dx = \frac{1}{6}\left[\left(\Delta u + \Delta\bar{u}\right) - \left(\Delta d + \Delta\bar{d}\right)\right] = \frac{g_A}{6}$$

Quark Contribution to the Proton Spin:

$$\int_0^1 \left[g_1^{\,p}(x) + g_1^{\,n}(x)\right]dx = \frac{5}{18}\left[\left(\Delta u + \Delta\bar{u} + \Delta d + \Delta\bar{d}\right) + \frac{2}{5}\left(\Delta s + \Delta\bar{s}\right)\right]$$

Gerasimov-Drell-Hearn Sum Rule (for Q$^2 \to 0$)**:**

$$\int_0^1 g_1^{\,N}(x,Q^2)dx = \frac{Q^2}{16\pi^2\alpha}\int_{\nu_{thr}}\left(\sigma_T^{\,1/2}(\nu) - \sigma_T^{\,3/2}(\nu)\right)\frac{d\nu}{\nu} = -\frac{Q^2}{8M^2}\kappa_N^2$$

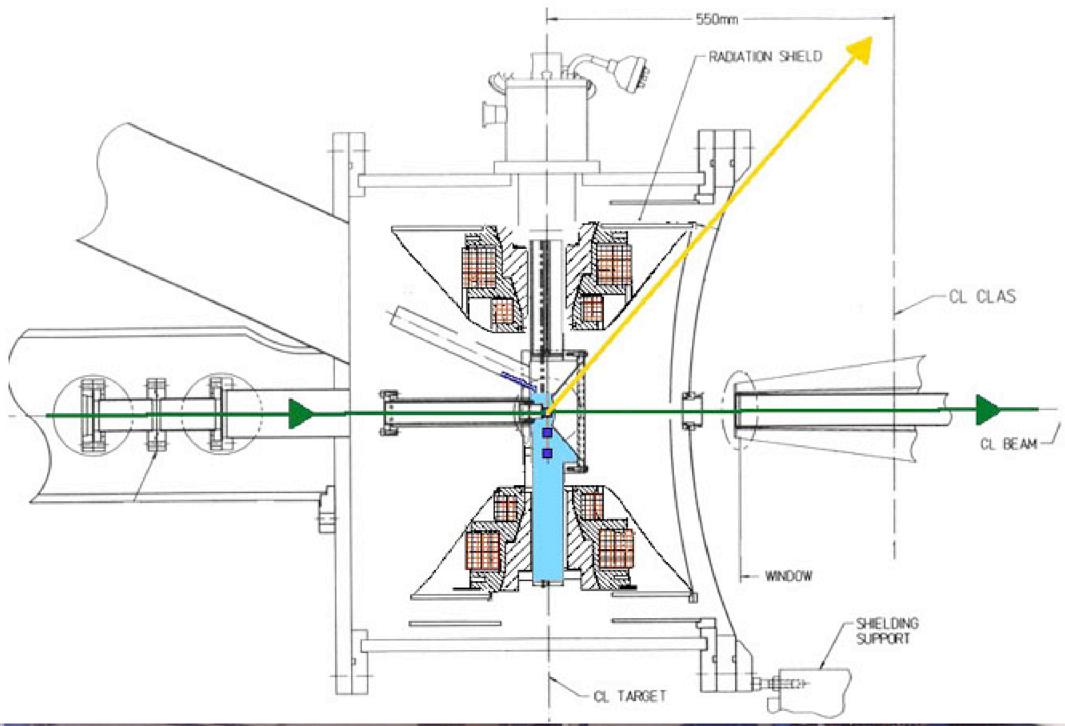
Spin-Isospin Decomposition of Resonant and

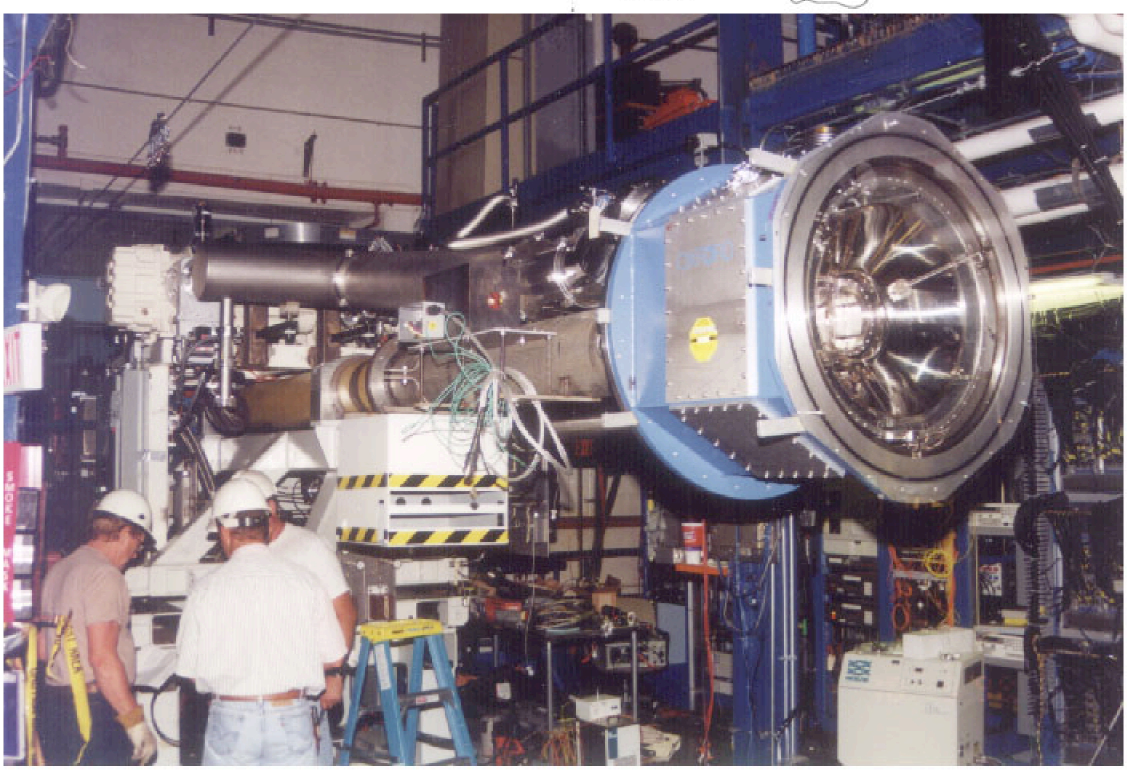
Background Amplitudes

How Neutrons?

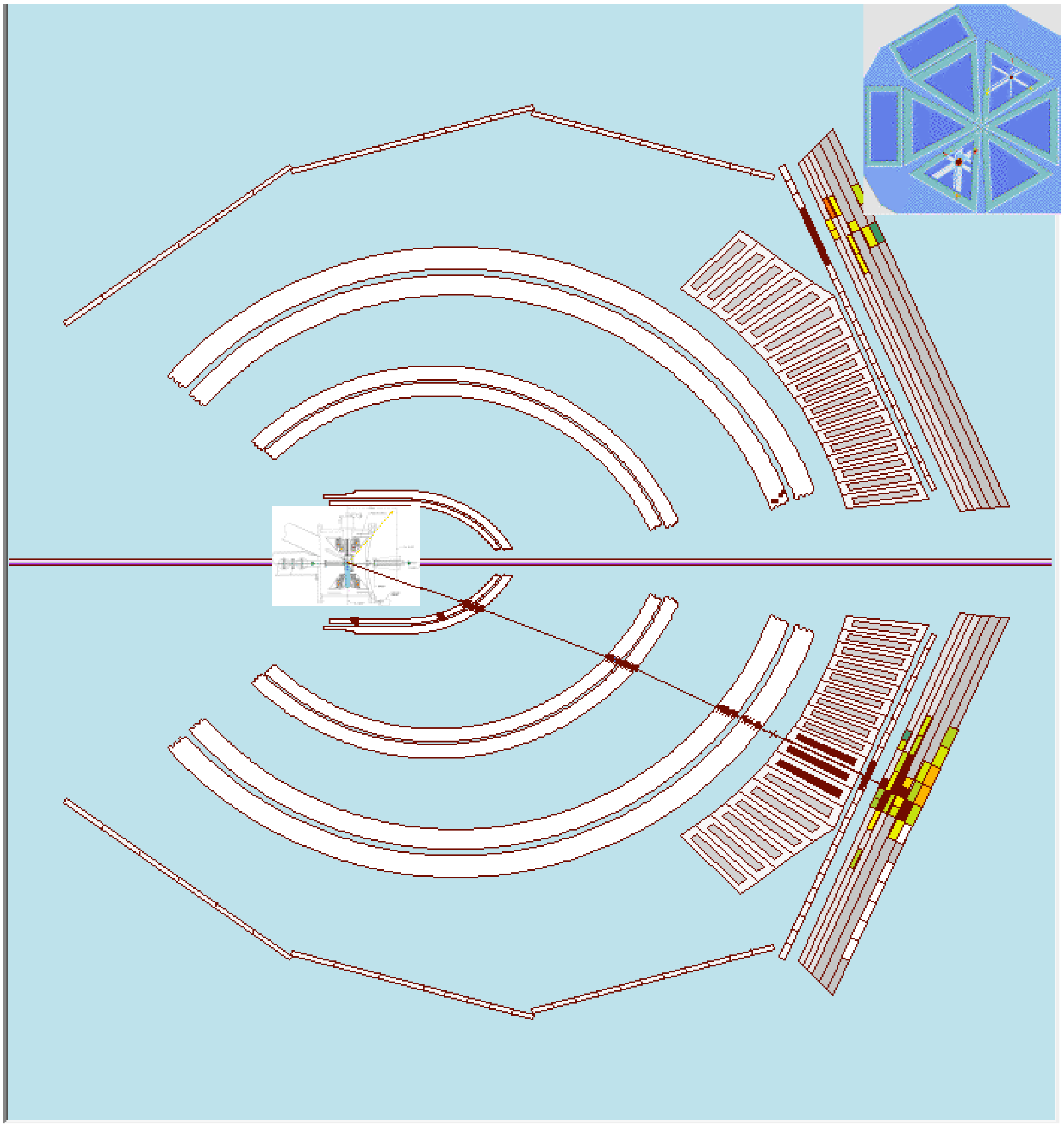
Polarized ^{3}He: approx. a polarized single neutron
Polarized ^{2}H: approx. a polarized proton and a polarized neutron

EG1a polarized target

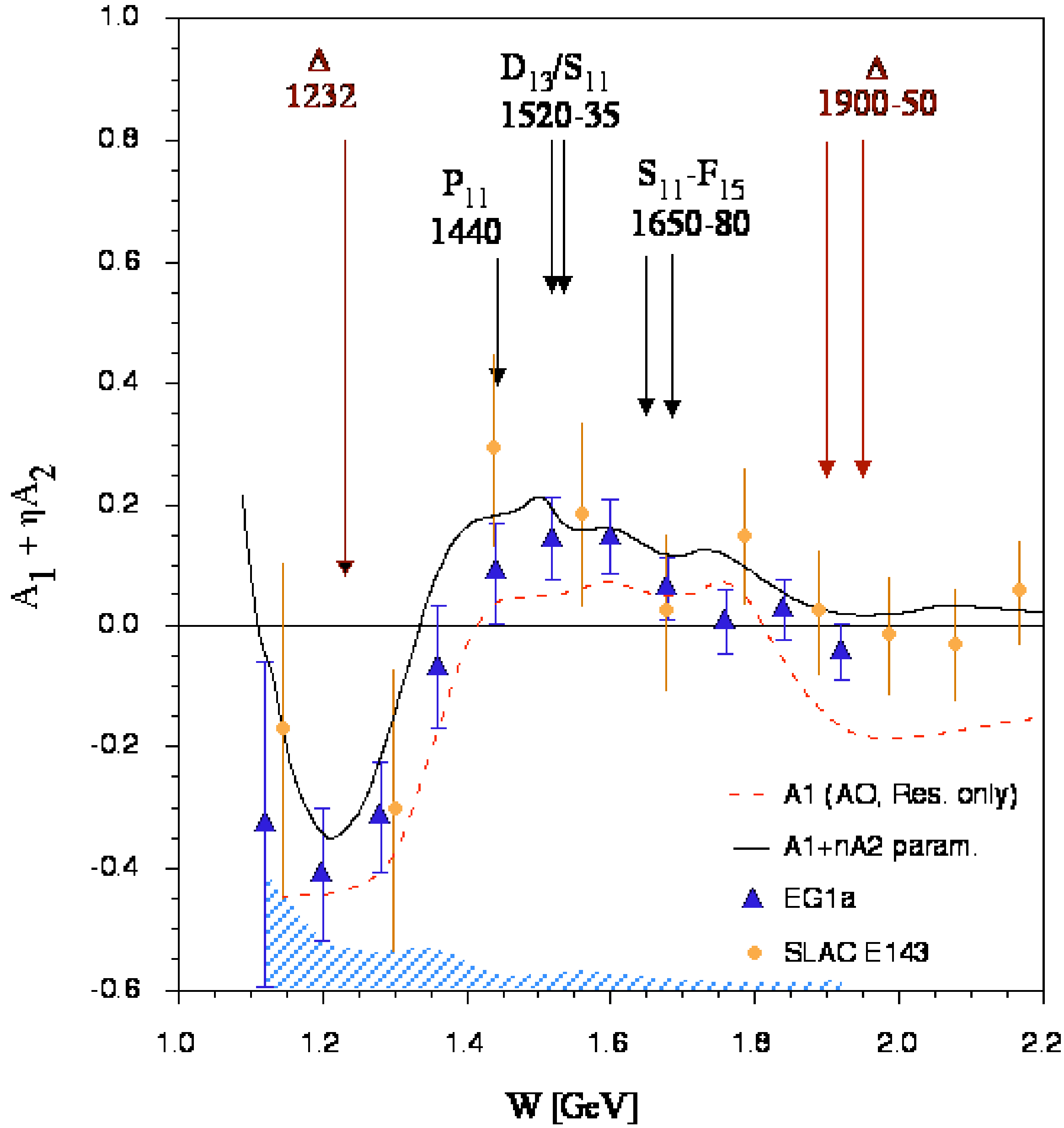




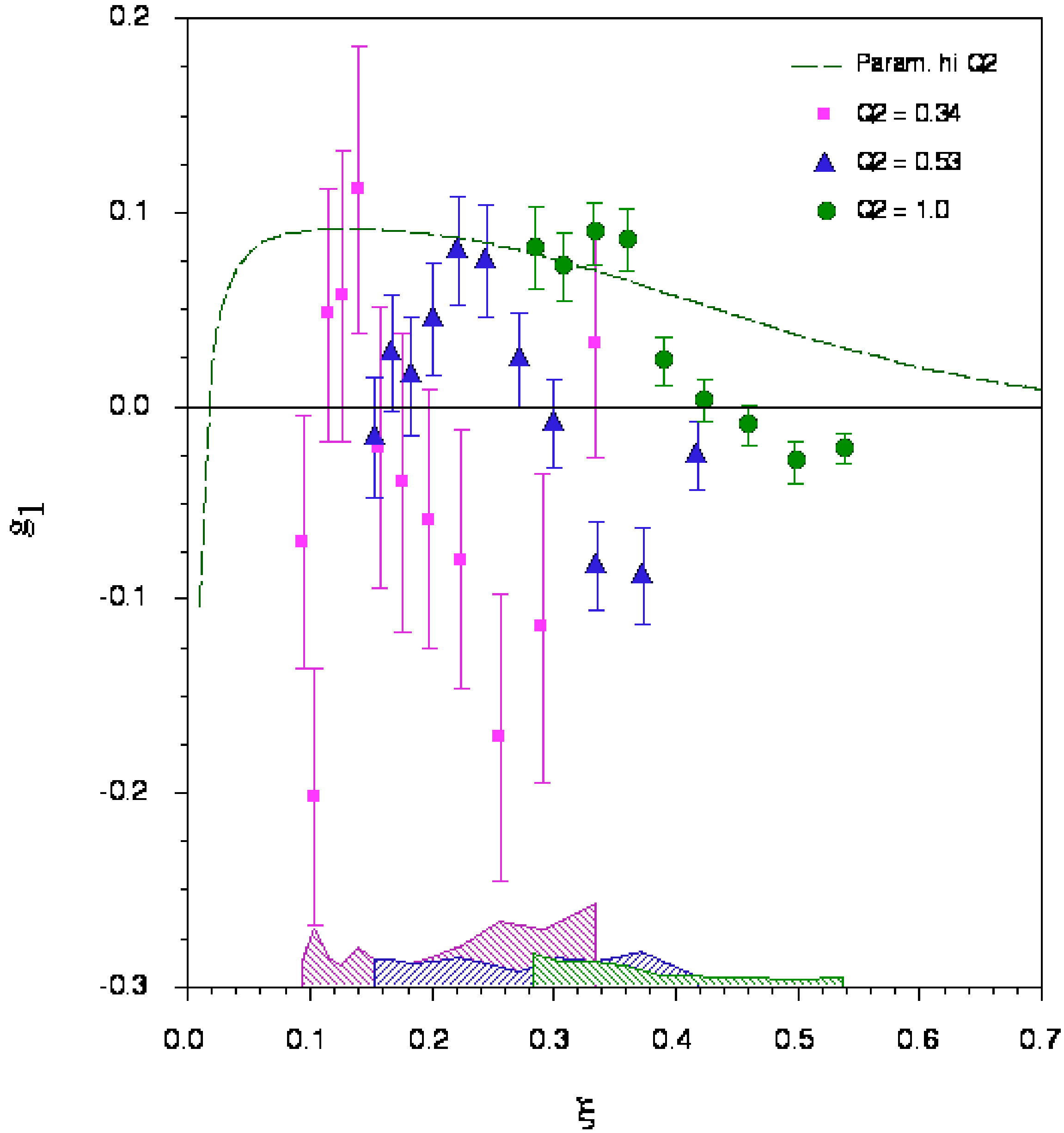
”Typical” Event in CLAS



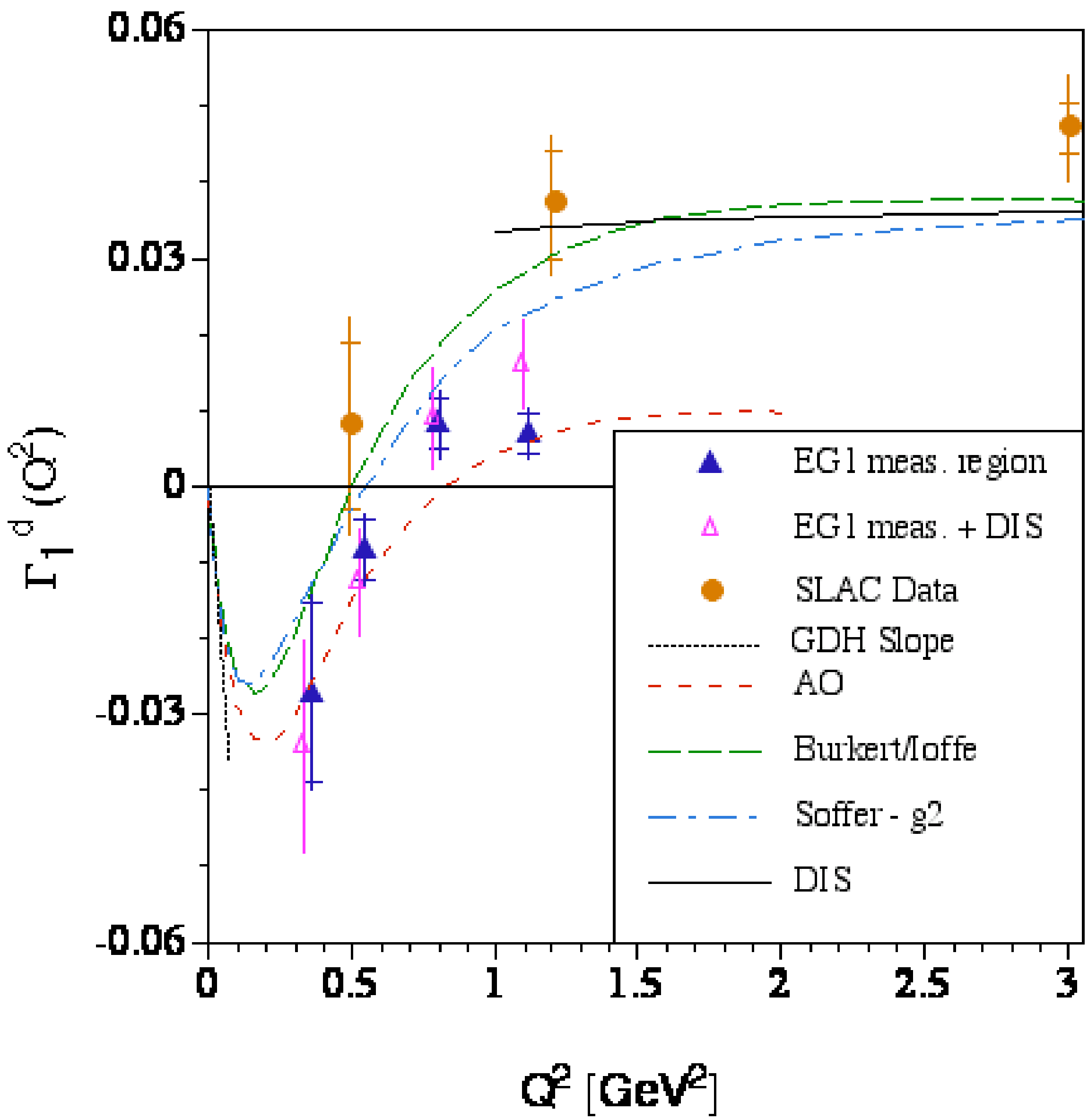
Asymmetry A_{1d} (with A_{2d} contribution)



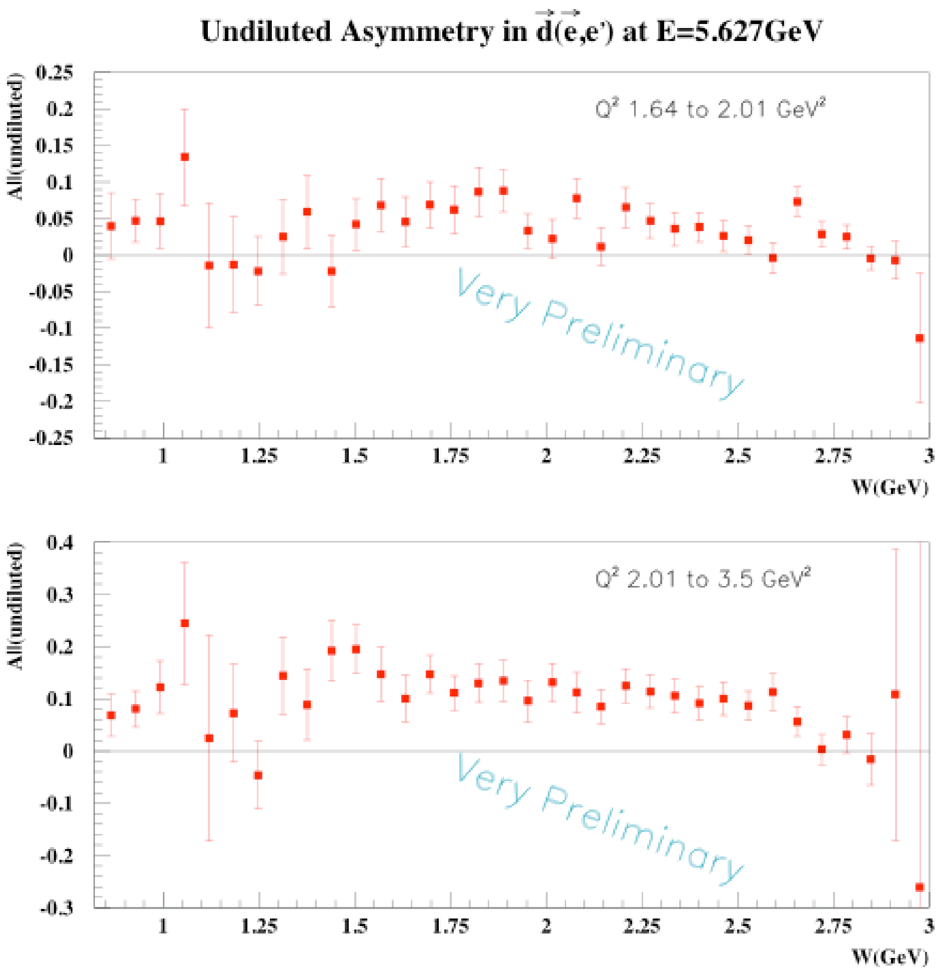
Structure Function g_{1d}



Integral Γ1d



The Future – EG1b (a.k.a. EG2000)

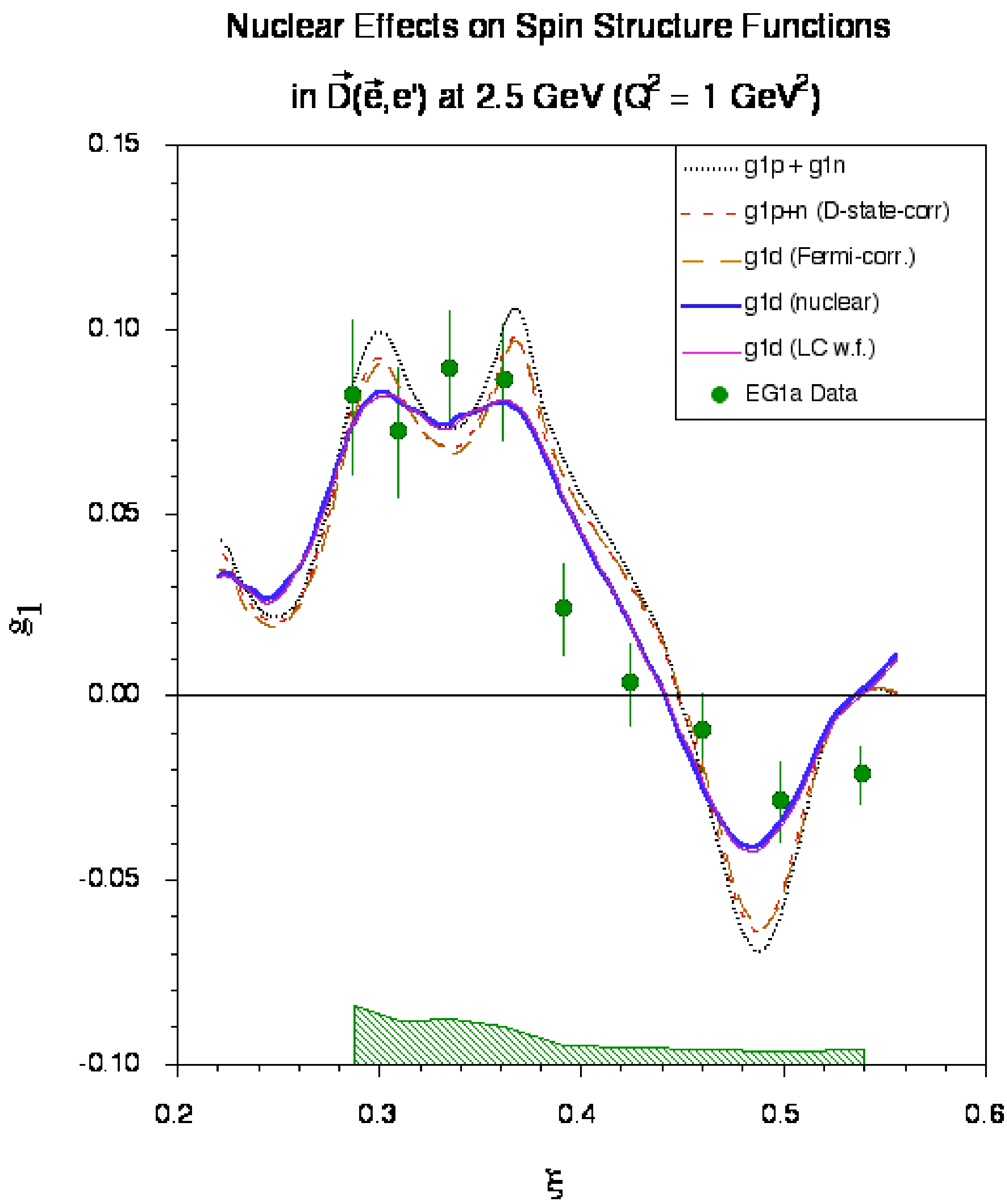


Nuclear Effects

	Deuterium↑	**^{3}He↑**
0^{th} order approximation	p↑n↑	p↑p□n↑
D-state, S' state etc.	$□_D = □_p + □_n - 0.022$	$□_{He} = □_n - 0.214$
Fermi motion	p_{RMS} = 130 MeV/c	p_{RMS} = 170 MeV/c
Binding Effects	E_{bound}-E_{free}□-10MeV	E_{bound}-E_{free}□-20MeV
Tensor Polarization	P_{zz} □ 0.1	n.a.
"EMC" Effects Final State interactions Coherent processes	□ □ 0.063 N/fm^3	□ □ 0.094 N/fm^3
Pre-existing □'s ?	$P_{□□}$ < 0.5%	$P_{□□}$ □ 2% ?
Pion excess?	2% ?	5% ?
Other exotic compon.?	??	??

Claim: Most of these effects (except D/S' state) are minor for integrals and for high Q^2 and W (DIS). Extracting information in the resonance region requires careful attention to "unfolding" procedure.

Modeling nuclear effects in D



Conclusions

- First data in the non-DIS region exist both on deuterium and ^{3}He. Many more data have been taken and are presently being analyzed.

- In the DIS region, nuclear corrections appear uncritical and the data from different nuclear species are in agreement.

- In the resonance region and at low Q^2, proper accounting for nuclear effects is more critical. Comparison between different nuclear species is really important – main sources of uncertainties are quite different between deuterium and ^{3}He.

- Several Experiments have taken data or are being planned to directly study nuclear effects on nucleon structure functions (EG1b, E6, BoNuS, …)